OAR Box 1824

Prepped by Charmelle Mathews

Document Number:

(159) IV-D-208

Docket Number:

A-90-16

A-90-16
IV-D-208

November 2, 1990

Dear Mr. Reilly

I urge you to reject Ethyl's application to use MMT.

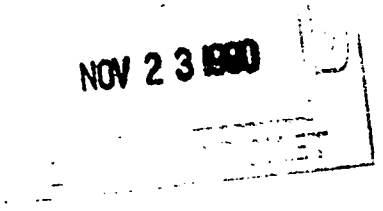
Enclosed are copies of articles documenting manganese poisoning.

--environmental risk factors in Parkinson's disease.

--"Parkinson's Bug"

In addition to rejecting Ethyl's application to use MMT, all other gasoline companies should be checked for their use of MMT and have them cease using this additive.

Sincerely
Orvo E. Markkula
Orvo E. Markkula
St. Lawrence Cty. Environ. Council



A-90-16
IV-D-208

Office of the Executive Director

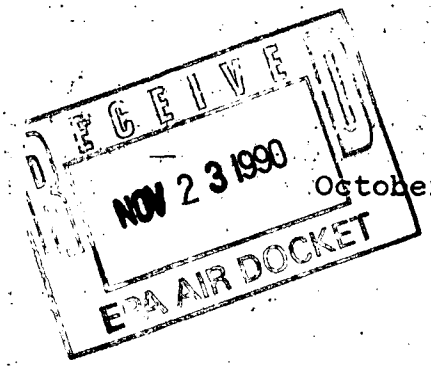
Environmental Defense Fund

257 Park Avenue South
New York, NY 10010

Arno — Here is the mailing I mentioned in our phone conversation

*** 7003 00953 1 ZP 0.205 BFED285A ***

Ms. Ruth Beebe
10 1-2 Leroy Street
POTSDAM NY 13676-1739



October 16, 1990

Dear Ms. Beebe:

I've had just about enough of the Ethyl Corporation. And once I tell you about the scheme that they're trying to put over on the U.S. population, I think you'll agree.

- The Ethyl Corporation of America is asking the EPA to approve a gasoline additive it calls "HiTec 3000."
- Ethyl Corp. has launched a full-blown ad campaign that misrepresents this new additive as both safe and environmentally beneficial.
- In reality, "HiTec 3000" contains manganese, a toxic heavy metal known to produce symptoms of Parkinson's disease at high doses.
- Adding "HiTec 3000" to gasoline will release into the environment large amounts of manganese, whose long-term effects on human health are unknown.

In other words, the Ethyl Corporation wants permission to use the entire U.S. population as test subjects in a very profitable experiment on chronic exposure to a toxic heavy metal.

And it won't be the first time!

Since 1925, Ethyl Corporation has championed the use of leaded gas, and has been the chief supplier of lead gasoline additives now known to have been a major contributing cause of chronic lead poisoning affecting millions of children around the world.

New research reveals a virtual lead poisoning epidemic among our nation's children, both urban and rural, rich and poor. Much of that lead -- ingested from dust and dirt in yards and playgrounds -- came out of the tailpipes of cars that burned leaded gas over the past 65 years. Cleaning up this contamination will be both slow and expensive.

Now, for the sake of its own profit, Ethyl Corporation is again ready to put our environment and public health at serious risk.

Luckily, you and I have until November 6th to stop them.

(over, please)

Ethyl has until November 6th to convince EPA to approve HiTec 3000. And it has been running full page ads in major newspapers in a shameless effort to lure the public and the Administration into believing that its new additive is safe.

This is one of those rare chances we have to nip an environmental disaster in the bud. Here are the 3 steps I ask you to take immediately:

1. Add <u>your</u> name to our "Open Letter to the EPA" to appear in a major newspaper advertisement from EDF (see the enclosed draft) to help us tell the real story on Ethyl Corporation to newspaper readers.

2. <u>Double</u> the power of your protest by writing a short personal note to Administrator William K. Reilly, Environmental Protection Agency (401 M Street, SW, Washington, DC 20460).

3. Send your generous gift <u>to support the newspaper ad</u> and to help EDF continue this critical campaign.

You know that EDF can get results. Our persistent campaign against leaded gasoline helped win its large scale phasedown during the 1970's. But this was a battle we might never have had to fight, had Ethyl Corporation acted responsibly from the start.

You see, the hazardous potential of the original lead gasoline additive was never a secret to Ethyl. Back in 1925, 40 workers at Ethyl's first plant were stricken with lead poisoning and five of them died from it. But Ethyl Corp. ignored the obvious warning sign -- that these cases of acute poisoning foreshadowed a possibly tremendous chronic problem . . . once millions of tons of lead-laden car exhaust were pumped ino the environment.

We simply can't let Ethyl Corp. put another toxic heavy metal additive in gasoline! There's no reason to open our environment to a new health hazard. We can't tolerate future unknown clean-up costs when this problem is altogether <u>preventable</u> today. And with your help, and the 3-step plan I've sketched above, we won't have to!

Ethyl Corporation managed to fool the public once . . . and the resulting damage to the environment and public health, much of it irreparable, is done. All we can say now is "Shame on them."

But if we let them do it again, shame on us!

Yours truly,

Fred Krupp

Fred Krupp
Executive Director

P.S. Please sign and return <u>immediately</u> the Authorization to add your name to our Open Letter. I must receive it no later than October 29th to meet our newspaper deadline. And thanks in advance for your help!

Ethyl has until November 6th to convince EPA to approve HiTec 3000. And it has been running full page ads in major newspapers in a shameless effort to lure the public and the Administration into believing that its new additive is safe.

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A New Idea from the Folks Who Gave Us Leaded Gas

By EDF toxicologist Dr. Ellen K. Silbergeld, who was the only environmentalist to appear before the Environmental Protection Agency (EPA) to urge rejection of an application to use a manganese-based compound as a gasoline additive.

In 1925, the Ethyl Corporation introduced its new gasoline additive, tetraethyl lead, as "a gift of God." It took us over 50 years to realize how diabolical this "gift" proved to be. The hard-won *removal* of most lead from gasoline represents one of EPA's most significant public health achievements. I am proud to have participated with EDF in that victory.

ELLEN K. SILBERGELD

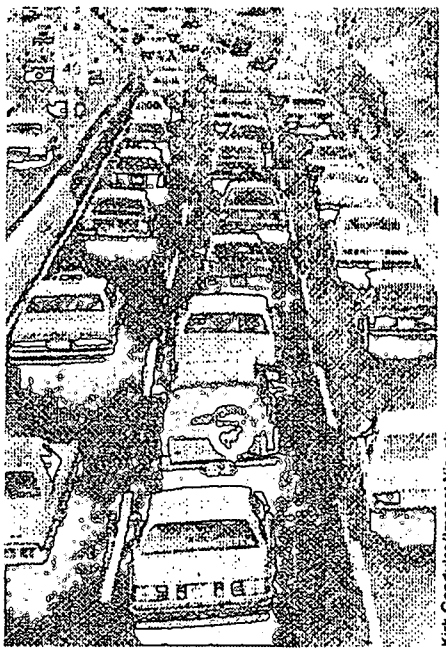
Now, in 1990, Ethyl comes bearing yet another gift, methycyclopentadienyl manganese tricarbonyl (MMT), and asks EPA to approve it as an octane-enhancing gasoline additive. To this offering, EPA must just say "No."

Lead poisoning is an epidemic in the U.S. Even after considerable reductions have been imposed on the use of lead in gasoline—only after prolonged debate and litigation, it should be noted—we are just now confronting the extraordinarily difficult challenge of cleaning up the residues of lead fallout from playgrounds, roadsides, and backyards in America.

Amazingly, in light of the history of leaded gasoline, Ethyl finds it unnecessary to do anything more in 1990 than it did in 1925.

The parallels between Ethyl's 1990 proposal to use manganese and its 1925 lead proposal are chilling. The exclusive justification for each additive is its purported effect on emissions of hydrocarbons and nitrous oxides from cars. No data were or are given on the potential cumulative health effects of massive inputs of a toxic metal into the environment, its deposition on surface dusts and soils, or its long-term fate and pathways of exposure to humans.

In 1925, Ethyl argued that the amounts of lead to be added to gasoline were negligible and that lead was only toxic at the high doses encountered in certain industrial settings. In 1990, it argues that the manganese releases to the environment will be insignificant and that manganese is only toxic at high doses in industrial settings.



Kirk Condyles/Impact Visuals

With ever-increasing numbers of cars on the road, manganese added to gasoline would—like lead—accumulate in the environment with potentially tragic results, particularly in urban areas.

In both cases, the critical national importance of accepting Ethyl's additive is argued. In a well-funded ad campaign claiming that MMT can reduce tailpipe emissions, Ethyl is seeking to exploit public concern over pollutants in global and local air. The purported reductions, if any, are very small and are overwhelmed by the health costs of exposure to manganese.

Amazingly, in light of the history of leaded gasoline, Ethyl finds it unnecessary to do anything more in 1990 than it did in 1925. Ignoring contrary evidence, it selectively cites bits of data to support its contention that the use of MMT will not increase airborne manganese concentrations over cities, and provides no data on the impacts of manganese additives on manganese levels in other parts of the environment. It presents no in-depth review of the health effects of manganese, nor—more important—any discussion of critical gaps in the data about manganese toxicity that must be filled before a decision that could release many thousands of tons of manganese to the environment can be approved.

The data on manganese are relatively sparse compared to lead—we have not yet conducted a massive human experiment with manganese. But *both what we know and what we do not know* about the likely toxic effects of adding large amounts of manganese to the environment must persuade EPA to reject this application.

We know that manganese at high dose is a demonstrated human neurotoxin, with persistent and irreversible pathological effects on brain structure and resulting severe impairments in movement and mental state. We have indications that manganese may also selectively affect the fetus, the young, and the aged.

We do *not* know what the long-term chronic, low-dose effects of human exposure to manganese are. We do *not* know what a "safe" level of manganese exposure is, particularly for the young or the aged who may be at increased risk. We do *not* know if manganese is carcinogenic, although there is evidence that it can break DNA, which may indicate cancer-causing potential.

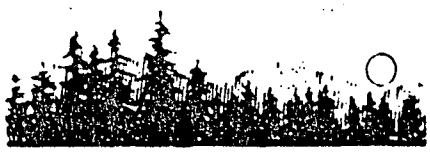
But from our tragic experience with lead, we know a great deal about the likely cumulative effects of such a use upon human exposure. We know that the gradual contamination of the environment by manganese will not be readily reversed. We know that manganese will accumulate in many places—particularly in urban dusts and soils—that are subject to intensive human interaction and that will be sources of direct human exposure to manganese.

Society cannot afford to repeat the public health catastrophe associated with the use of lead in gasoline.

We rarely have an opportunity to apply the clear lessons of 50 years of very similar experience. To disregard these lessons by approving the widespread and inevitably dispersive use of manganese would be to invite repetition of the public health catastrophe associated with the use of lead as a gasoline additive since 1925. Society cannot afford such a repetition. EDF is urging EPA to reject this new application and immediately suspend all currently permitted use of manganese as a gasoline additive in the United States.

EDF MEMBER ACTION ALERT

Concerned members can help by writing to EPA Administrator William K. Reilly (Washington, DC 20460) urging him to reject Ethyl's application to use MMT.



St. Lawrence County
ENVIRONMENTAL MANAGEMENT COUNCIL
Courthouse Canton, N. Y. 13617 (315) 379-2281

April 25, 1989

Mark Stoddart
Health/Mental Health
Box 229, SUCP
Potsdam, NY 13676

Dear Mr. Stoddart:

The enclosed information is being forwarded on to you at the request of the Planning and Conservation Committee for possible consideration by the Health Committee.

Sincerely,

Nancy Cady

Nancy Cady
Confidential Secretary

enclosures

TO: Mr. Berton Mead, DEC
FROM: Orvo E. Markkula, SLC-EMC Member
RE: Mechanical Accumulation of Dusts From Water Sprayed into the Air by Some Humidifiers
DATE: March 21, 1989

Dear Berton,

I am enclosing materials to document my acquiring some Parkinson-type symptoms such as:

1.) An at-rest tremor in right forearm

2.) An unsteady short stride in walking

3.) Some loss of balance when standing (especially on one foot)

4.) Aches and pains in joints

I was referred to Dr. Robinson, a neurologist in Watertown, by Dr. Sebastian Mazzotta, Canton, N.Y. When asked whether the cause was lead or mercury poisoning, Dr. Robinson said NO! It was manganese.

I started to research the literature. The Handbook of Manufacturing Materials revealed that most steels contained manganese. Also, it was an alloying material in aluminum alloys (up to 30%). Further, manganese is 62% of the flux on welding rod.

My well is located across the road from The Auto Shop which does auto-body work, mufflers, etc., and also does painting, washing and polishing of cars. This place is a non-conforming land use in a one-family residential zone. I have been unable to stop this operation because of non-enforcement by town officials. I had my water tested for manganese (see test results). My water tested .03 MG/L whereas the DOH limit is .3 MG/Liter (a ten fold difference).

However, Jon Montan, a staff worker in the SLC EMC called my attention to a study on accumulations that result from using humidifiers which spray water into the air - the water evaporates leaving as dust any substances which were dissolved in the water. In a typical area being humidified, the study found a 200 fold accumulation of these substances. This changes the ratio of being on the permitted side by a factor of 10 to a ratio of exceeding the permitted one of .3 MG/liter by a factor of twenty! The National Academy of Sciences study Manganese (1973) points to factors which indicate that acid-rain, use of manganese (24% of the anti-knock substance in un-leaded gasoline) creates situations where iron and nickel carbonyls are formed. These two manganese compounds are especially carcinogenic. Manganese must be considered a dangerous

sleeping giant which is being awakened by man-made changes.

The public needs to know the potential danger from using water other than distilled water in spray-type humidifiers.

I had discontinued using the Herrmidifier attached to and blowing a spray of well water into the cold air plennum of my hot-air furnace several years ago because of the layer of dust on everything. I realized that we were breathing in considerable amounts of this dust.

Acid rain, from whatever sources - car emissions, incinerators, aluminum smelters, fossil-fuel power plants - makes manganese oxide readily soluble in water to percolate into ground water.

I imagine that spray-type humidifiers could also introduce disease organisms from polluted water and result in accumulations that would be deadly - recall the 60 Minute documentary several years ago on The New River flowing from Mexico into Southern California - foam blowing into a parking lot contained 2800 different kinds of organisms - (called the most polluted river in the U.S.).

DATE: April 18, 1989

TO: Persons using Humidifiers during times when indoor air tends to be very dry; and upon heating the air, the relative humidity becomes even lower which results in chapped lips and dry nose and throat.

FROM: Orvo E. Markkula, St. Lawrence County Environmental Management Council Member

SUBJECT: DANGERS OF USING WATER, OTHER THAN DISTILLED WATER, IN SPRAY-TYPE HUMIDIFIERS

One who uses this kind of equipment could be practicing Chemical Warfare, Germ Warfare or afflicting one's family with Silicosis or Fungus Infection in their respiratory tract.

All tap water and well water, even rain water, has different kinds and amounts of minerals dissolved or suspended in it. One can get some idea of the amount by boiling off the water in 1/2 teaspoon of water on a hot plate. The residue left on the spoon consists of the minerals that were in that amount of water. How many 1/2 teaspoonfuls are there in a gallon of water?

In a normal 6- 8-hour period of using a humidifier, during occupancy, one would spray 4 to 6 gallons of water into the air--including any minerals therein.

A study was conducted in Boise, Idaho and published in "Environmental Science Technology" 1988, 22, 1109-1112. The study was sponsored by EPA, Environmental Monitoring Laboratory, Research Triangle Park, North Carolina, 27711. The study was conducted with appropriate controls for comparison and leaving the only variable, a spray-type humidifier.

There were some amazing concentrations of minerals in the air--the heavier particles of impeller-type sprayers settling over everything in time and the lighter particles remaining suspended--to be breathed into the lungs of occupants. Because there is less transfer of air to the outside when using a humidifier, the minerals accumulate by a factor of 200 (if the water tests .03 mg/L or .00003 grams per liter) of manganese, as in my case; and the permitted level is .3 mg/L. Then my well water would have to have ten times the manganese before exceeding the Department of Health permitted level of .3 mg/L.

However, with an accumulation by a factor of 200 of manganese, my measured amount of .03 mg/L becomes 6.0 mg/L or Twenty Times the permitted amount of pollution.

Small wonder, then, that over a 30-year period of using a Herrmidifier impeller-type of humidifier which would spray into the cold air plenum (up to 6 gallons/day whenever the Humidistat called for water), that I developed some of the symptoms of manganese poisoning--an at-rest tremor in my right forearm.

The medical and biological effects of environmental pollutants is well documented in a publication by the National Academy of Sciences, Committee of Biological Effects of Atmospheric Pollutants, Division of Medical Sciences National Research Council, Washington, DC, 1973, entitled "Manganese." Chapter 10 "Manganese Tricarbonyl Compounds" covers toxicity studies if increased use of MMT (unleaded gasoline anit-knock additives--up to 24% by weight of manganese carbonyl compounds) the nickel carbonyl is especially carcinogenic (cancer producing).

Manganese occurs in all steels--up to 30% in certain tough steels. Up to 30% manganese in aluminum alloys. Up to 62% manganese in flux on welding rod, and manganese also occurs in battery fabrication.

From page 126, "Manganese Tricarbonyl Compounds," "...Concerns about public health are related to the aerial discharge of manganese substances that are then inhaled by persons who live in the immediate vicinity and to the occasional infiltration of local water systems with significant amounts of manganese, mostly through location of solid-waste disposal facilities or through contamination of water supplies from sanitary landfills."

Acid rain, from whatever source--car emissions, incinerators, aluminum smelters, fossil-fuel power plants, makes manganese oxide more readily soluble in water--to percolate into ground water.

The safest humidifier is one which makes steam and which leaves the minerals behind as a deposit. Distilled water is safe in all humidifiers. The ultra-sound types are the worst offenders.

ATLANTIC TESTING LABORATORIES, LIMITED

Sustaining Member—N.Y.S. Society of Professional Engineers

atl

Box 29
Canton, N.Y. 13617
(315) 386-4578

Box 356
Cicero, N.Y. 13039
(315) 699-5281

June 7, 1988

Orvo Markkula
P.O. Box 389
Canton, New York 13617

Re: Sample Number 88-659
ATL Report No. EL001N-373-6-88

Dear Mr. Markkula:

The water sample submitted by you to Atlantic Testing Laboratories, Limited on May 24, 1988 contained <0.03 mg manganese/L. The limit set by the New York State Department of Health is 0.3 mg manganese/L.

Please feel free to contact our office if we can be of further assistance.

Sincerely,

Marijean B. Remington

Marijean B, Remington
Environmental Laboratory Director
NYS DOH ELAP NO. 10819

MBR/lja

DISCLAIMER: All sampling services and analytical procedures are performed in accordance with recognized analytical methodologies. The full extent of any and all liability for actual and consequential damages for the services performed shall be limited to reperformance or cost of said work. ATL is not liable for data interpretation by others.

Environ. Sci. Technol. 1988, 22, 1109-1112

Indoor Particle Concentrations Associated with Use of Tap Water in Portable Humidifiers

V. Ross Highsmith* and Charles E. Rodes

Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711

Richard J. Hardy

Morrison-Knudsen Engineers, Boise, Idaho 83709

■ A study was conducted in Boise, ID, residences to investigate the impact on indoor air quality of using tap water in portable home humidifiers. Commercially available units tested with tap water of known dissolved solids content included ultrasonic, impeller, and steam. Samples were collected for gravimetric analysis along with information on temperature, relative humidity, and air-exchange rates. Fine particle concentrations measured in the bedroom of one residence were greater than 590 $\mu g/m^3$ when an ultrasonic humidifier was operated in the kitchen using tap water containing 303 mg/L total dissolved solids. Fine particle concentrations in excess of 6300 $\mu g/m^3$ were observed when the ultrasonic humidifier was operated in a closed room situation. The impeller units generated less than one-third the aerosol mass generated by the ultrasonic humidifiers. A steam unit generated no measurable increase in PM_{10}.

Background

Homeowners have historically used portable humidifiers to provide direct relief from dry air discomfort symptoms such as dry nose, throat, and lips. Physicians routinely prescribe the use of humidifiers and vaporizers upon diagnosing respiratory illnesses ranging from colds to severe asthma. Humidifier use generally increases during the winter months when indoor relative humidities fall below 40–50%, the optimum level for maintaining personal comfort while minimizing adverse direct and indirect humidity associated health effects (*1*).

Conventional portable home humidifiers, employing steam or impeller technology for moisture dispersion, are rapidly being replaced by technologically advanced ultrasonic humidifiers. Ultrasonic humidifiers have several advantages over steam or impeller models. They are extremely quiet, are able to humidify larger areas, and may reduce the mold and bacteria problems associated with the conventional models (*2*). Their operating principle is not new; aerosol scientists have used ultrasonic nebulization technology to generate test aerosols for many years (*3*). A problem noted during recent testing of portable home humidifiers is the "dread white dust" that settles on horizontal surfaces in close proximity to the humidifier (*2*). This dust, which results from minerals dissolved in the water, has been considered too large in aerodynamic diameter to be a significant health problem. The overall impact on indoor pollution levels and ultimately on human health obviously depends on the source and chemical composition of the water used in the humidifier, the proximity of the individuals to the humidifier location, and the number of hours the residents are exposed to humidifier-generated aerosol. Homeowners have no direct control over the inherent mineral content of the often municipally supplied tap water entering their residences. They do, however, have a choice of purchasing bottled demineralized water or demineralizing their tap water before using it in the humidifier. Manufacturers, aware of the dissolved mineral nebulization problem, currently recommend in the unit instructions that the user purchase distilled or deionized water or pass their tap water through the demineralization cartridges included with the units. Some manufacturers warn owners that exposure to the white dust may be hazardous to their health, but provide no real basis for their warning. Most homeowners appear to be ignoring these warnings because the added costs and inconvenience associated with using either low mineral content water or a demineralizing cartridge are not nearly as attractive as operating the unit with readily available tap water.

An indoor air monitoring program was conducted in Boise, ID, from November 1986 through February 1987 to evaluate the impact of in-use wood-burning appliances on indoor air quality (*4*). Matched pairs of adjacent residences, one with and one without an operating wood-burning appliance, were monitored continuously over a 4-day period. The home selection process excluded residences with other known particle-emitting sources, including tobacco smoke, to minimize emissions confounding the tests. A review of the concentration data collected at one of the non-wood-burning residences revealed unexpectedly high concentrations of fine particles ($D_a \leq 2.5$ μm, aerodynamic diameter) in excess of 80 $\mu g/m^3$. These concentrations were as much as 5 times the corresponding fine particle levels observed either in the adjacent wood-burning residence or immediately outdoors. A reexamination of the field data, the homeowner activity journals, and a return visit to the residence revealed that the only apparent aerosol source in use during sample collection was an ultrasonic humidifier located in a sick child's bedroom. Although the humidifier manufacturer recommended the use of distilled or demineralized water, the homeowner had used tap water. The humidifier operating times noted in the resident's activity journal correlated with increased fine particle concentrations as measured in the residence by a nephelometer, tentatively identifying the ultrasonic humidifier as the primary contributor of the increased particle concentrations. After the approximate mineral content of the water was obtained, a quick computation projected that virtually all of the dissolved impurities were apparently released with the vapor into the indoor air. The fact that the particle sizes were predominantly smaller in diameter than the respirable cut point made the unexpected discovery even more surprising.

Experimental Section

To confirm the preliminary measurements that identified the humidifier as a significant aerosol source, a more structured follow-up study was conducted in Boise from October 1987 through January 1988. The limited resources available for this investigation necessitated that the study design focus primarily on verifying the initial study findings and better defining the potential magnitude of the

problem. Five commercially available portable home humidifiers (two ultrasonic, two impeller, and one steam) were operated separately inside one Boise residence from October 1987 through January 1988 to investigate the impact of whole-house and single-room humidification on indoor air quality. The ultrasonic units employ electronic transducers to nebulize the water into small droplets. The impeller or "cool-mist" humidifiers use a spinning impeller to draw water from a reservoir and drive it outward at high speeds against a ring of staggered baffles, breaking the water into droplets. The steam unit generates water vapor by thermal evaporation. One ultrasonic humidifier (UH-1) was identical with the unit used in the earlier EPA study. Each humidifier was located in the kitchen of a typical residence (volume = 392 m^3) to represent whole-house use. Each was operated with the controls set at the maximum water consumption rate (WCR, L/h). Concurrent sampling was conducted for 6–8 h in a bedroom located at the opposite end of the house using a Sierra-Andersen Model 241 PM_{10} dichotomous sampler. A low-flow-rate (ca. 0.150 L/min) open-face filter was used for 1–2 h during each sampling period to collect samples for microscopic examination. Weathertronics Model 5010 hygrothermographs recorded relative humidity and temperature in both the bedroom and kitchen. The house air exchange rate was determined via the sulfur hexafluoride (SF_6) decay method (5) with a Demaray Scientific Model SS12-12 automated syringe sampler set to collect 12 sequential 30-min integrated samples. (The mention of trade names or commercial products does not constitute endorsement or recommendation for their use.)

The primary ultrasonic humidifier (UH-1) was operated for 6–8 h at a second residence (volume = 283 m^3) to verify that the findings were reasonably independent of the environment being evaluated. Short-term samples (15–30 min) were also collected with the monitors and the UH-1 humidifier collocated in a bedroom (volume = 25 m^3) at a third residence. The bedroom door was closed and the forced-air heating system turned off during sample collection resembling the normal conditions for the use of portable humidifiers by homeowners. The short single-room experiment sampling times were necessary to prevent the filter overloading that resulted from the extremely high particle concentrations generated by the portable ultrasonic humidifier. Every attempt was made to conduct sampling at each residence during periods when the occupants were not at home to prevent exposing the occupants to potentially unhealthy concentrations of particles and to minimize the collection of aerosols generated by homeowner activity.

A bulk tap water sample was collected directly from a Boise public water system well. Municipal drinking water supplies normally combine the resources of multiple wells and reservoirs to support public demand as well as to minimize the mineral content of the water. Collecting the sample directly from the well eliminated possible singular contamination from residential plumbing. The selected sample was representative of the highest mineral levels observable in the area. Use of a sample containing relatively high concentrations of dissolved solids would ensure that the aerosol samples collected would contain sufficient concentrations of materials that could be easily analyzed by conventional techniques. Laboratory analyses of the bulk sample were conducted before and after the study and indicated that the total dissolved solids (TDS) averaged ~303 mg/L and a hardness of 145 mg/L. The results of two large-scale studies of drinking water suggest that the quality of the bulk water sample used in this experiment

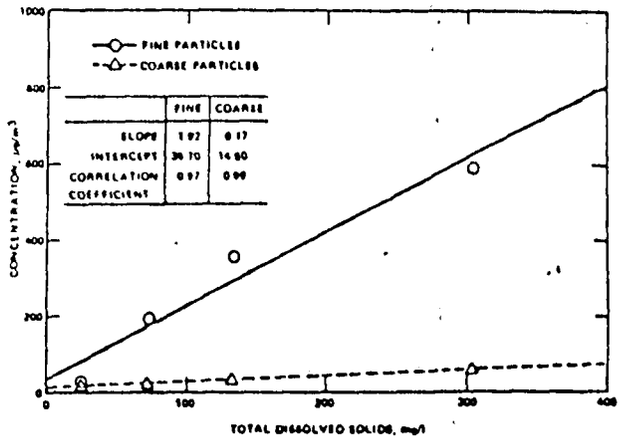


Figure 1. Mean particulate loadings vs total dissolved solids.

is typical of the municipal and rural drinking water supplies found across the United States. Craun et al. (6) evaluated the water collected from 4200 residences and reported water hardness values ranging from 6 to 270 mg/L with a mean value of 119 mg/L. A similar U.S. Department of Commerce survey (7) of nearly 22 million rural households scattered across the United States reported that the total dissolved solids content of these rural water supplies ranged from 5 to nearly 5950 mg/L with a mean value of 248 mg/L. Commercially available distilled water (TDS = 24 mg/L), purchased from a local grocery store, was used to simulate conditions recommended by the humidifier manufacturers. The distilled water was mixed with the tap water to prepare intermediate dissolved mineral sample concentrations of 72 and 133 mg/L, providing a range of TDS concentrations to be used in the tests.

The dichotomous sampler and nephelometer were calibrated and operated in accordance with the manufacturers' specifications. The hygrothermagraphs were checked daily with a fan-aspirated psychrometer. Gelman TEFLO 37-mm filters for gravimetric determination were conditioned (20 °C, 40% RH) for 24 h prior to tare and gross weighings on a Mettler ME-22 microbalance. Nontared Nuclepore filters (0.2-μm porosity) were used to collect samples for microscopy. SF_6 concentrations were determined by using standard electron capture detection gas chromatography.

Results and Discussion

Whole-House Experiments. The indoor air aerosol concentrations measured at the primary residence when UH-1, operated for 6–8 h as a whole-house unit, was charged with water containing a range of total dissolved solids are graphically displayed in Figure 1. The air-exchange rate measured during these experiments was 0.44 h^{-1} with the house relative humidity increasing moderately from approximately 35% to nearly 45%. An averaged fine particle concentration of 593 μg/m^3 and coarse-to-fine particle ratio of 0.11 was observed when the undiluted tap water was used in the humidifier. Operating the ultrasonic humidifier under manufacturer recommended conditions with commercially available distilled water (TDS = 24 mg/L) yielded averaged fine concentrations of 27 μg/m^3 and PM_{10} concentrations of 43 μg/m^3, which can be compared to the true house background values of 11 μg/m^3 fine and 19 μg/m^3 PM_{10}. Comparisons between mean particle concentrations and water TDS concentrations yielded linear regression correlation coefficients exceeding 0.97. The scatter observed in the regression is attributed to small temporal variations in air-exchange rate. Preliminary runs

Table I. Comparison of Particle Concentrations Observed at the Primary Residence[a]

humidifier code	WCR,[b] L/h	sample time, h	particles, $\mu g/m^3$ fine (0–2.5 μm)	coarse (2.5–10.0 μm)	total (0–10.0 μm)	ratio coarse/fine	ratio fine/total
UH-1	0.48	6.0	593	65	658	0.11	0.90
UH-2	0.35	6.6	378	48	426	0.13	0.89
(UH-2)[c]	(0.48)		(528)	(67)	(595)		
IM-1	0.17	8.4	146	45	191	0.31	0.76
(IM-1)[c]	(0.48)		(408)	(126)	(534)		
IM-2	0.09	7.8	33	23	56	0.70	0.59
(IM-2)[c]	(0.48)		(183)	(128)	(311)		
ST-1	0.34	6.8	16	25	41	1.56	0.39
(ST-1)[c]	(0.48)		(23)	(36)	(59)		

[a] Residence volume = 392 m^3; AER = 0.44 h^{-1}; TDS = 303 mg/L. [b] WCR = water consumption rate. [c] Normalized to UH-1 water consumption rate.

indicated that at least one and preferably two air exchanges were required before near-steady-state conditions were achieved. Fine and coarse regression y intercepts (Figure 1) compared well with the corresponding background concentrations.

Indoor particle concentrations are difficult to predict because of factors such as incomplete mixing and settling. The impact of ultrasonic humidifiers on indoor air quality (C_{air}, $\mu g/m^3$) should be predictable once the investigator knows the humidifier water consumption rate (WCR, L/h), the house or room air exchange rate (AER, h^{-1}) and volume (V, m^3), and the water mineral content (C_w, mg/L). Following the mass balance approach of Alzona et al. (8), a steady-state equation can be proposed:

$$C_{air} = \frac{C_w \times \mathrm{WCR} \times F \times 1000}{V \times M \times (\mathrm{AER} + K_L)} + C_b \qquad (1)$$

where M is a unitless factor for the degree of mixing, K_L (with units of h^{-1}) is the loss rate of particles due to settling, F is the proportion of particles generated in the collected size fraction, and C_b is the background concentration. For the whole-house situation with extended sampling times and a significant separation between source and receptor, it can be assumed that the degree of mixing approaches unity, especially for fine particles. By use of the slopes shown in Figure 1 and the ratios of fine/total and coarse/total from Table I for F, K_L is computed to be 0.14 h^{-1} for fine particles and 0.28 h^{-1} for coarse particles. The fine value is reasonable based on the theoretical settling velocities for particles less than 2.5 μm. The coarse value, however, is low by at least a factor of 3, indicating that M is obviously particle size dependent. A similar computation for PM_{10} (total in Table I), which had a regression slope against C_w of 2.09, yields a K_L value of 0.15 h^{-1}. The latter value essentially represents the fine particle value within experimental error, reflecting the preponderance of fine particles generated. For a given humidifier operating under constant conditions, the aerosol mass concentration appears to vary proportionately and predictably with the quality of the water.

The four other humidifiers were charged with the undiluted tap water and operated separately over a 6–8-h period at the primary residence. The observed indoor particle concentrations for this single TDS level (303 mg/L) are summarized in Table I. Normalizing the UH-2 consumption rate to the UH-1 WCR yields UH-2 particle loadings approximating the UH-1 values, implying that the only difference between the two ultrasonic units is water consumption rate. By comparison, impeller units IM-1 and IM-2 fine concentrations were significantly lower and represent only 25% and 6%, respectively, of the UH-1 fine concentration. This observed difference in impeller unit fine particle concentrations is attributed to their much lower water consumption rate. The impeller units exhibited a generation of larger particles with coarse-to-fine ratios exceeding 0.30, triple the corresponding ultrasonic humidifier values. Both sets of findings are most probably associated with the mechanical droplet generation process. No observable differences in design were noted that would explain the variability between the impeller units' fine particle concentrations or why the normalized IM-2 fine aerosol concentration was much less than either of the ultrasonic humidifiers or IM-1. The steam humidifier generated no measurable PM_{10} aerosol beyond typical background levels. Table I also lists the impeller and steam humidifier concentrations normalized to the UH-1 WCR. These calculations were performed for comparison purposes only, since the physical characteristics of impeller and steam humidifier units typically do not allow the user to vary the water consumption rate.

As a confirmation, two 6–8-h sampling periods were conducted at a second Boise residence with an AER of 0.35/h. Again, UH-1 was located in the kitchen, charged with 303 mg/L of water and operated under whole-house conditions. An averaged fine concentration of 491 $\mu g/m^3$ and coarse-to-fine ratio of 0.13 were observed. These values compare well with the primary residence values both in magnitude and in distribution between fine and coarse particle modes.

Single-Room Experiments. The particle sampler and UH-1, charged with 303 mg/L of water, were operated together over short periods (<0.5 h) in a closed bedroom with a volume of 25 m^3 to simulate more typical homeowner usage of portable humidifiers. An artificially high air-exchange rate of 1.16 was measured during sampling resulting from venting of the sampler exhaust outside the closed room. High humidity (>90%) and extremely high particle concentrations within the room limited the sampling time to less than 60 min to avoid overloading the filters. Alarmingly high concentrations of 6307 $\mu g/m^3$ fine, 771 $\mu g/m^3$ coarse, and 7078 $\mu g/m^3$ total PM_{10} were observed. Nearly identical results were obtained when the experiment was repeated, confirming these findings. Analysis of the single-room data using eq 1 is possible for the fine particle fraction assuming that the particle loss factor (K_L) is similar to the whole-house case. In the single-room experiment, the sampler was in close proximity to the aerosol generator and the sampling times were relatively short. It is highly probable that under these conditions the mixing factors were significantly less than unity. Substituting the K_L value of 0.14 and solving eq 1 for the mixing factor (M) gives a value of 0.53 which compares well with values found by Drivas et al. (9). Assuming a more normal AER of 0.5 and M = 1.0, the

single-room level would be calculated to have fine particle concentrations in excess of 7500 $\mu g/m^3$. The common usage of home humidifiers in bedrooms would lead to very high 24-h exposures, even if occupied for only 6–8 h per day. These extraordinary particle concentrations exceed the 5 mg/m^3 NIOSH threshold limit value for respirable particulate matter (*10*) and are nearly 50 times the EPA's new PM_{10} primary standard for ambient air of 150 $\mu g/m^3$ for a 24-h period (*11*).

Additional research is now in progress to characterize the composition, morphology, and size distribution of aerosol generated when using tap water in home humidifiers. This information, along with detailed tap water quality data, will be examined to better assess possible exposure levels to metals as well as to explore the potential health implications of home humidification. The results of these additional analyses as well as the conclusions will be presented in a later article.

Conclusions

The results from these preliminary experiments indicate that the use of tap water with typical mineral content water for home humidification using certain types of portable humidifiers can produce very high indoor air particulate mass concentration levels in excess of 7000 $\mu g/m^3$. Whole-house PM_{10} levels exceeding 40 $\mu g/m^3$ were observed even when the ultrasonic humidifier is operated using a sample of commercially purchased distilled water as recommended by the manufacturer. Equation 1 would predict fine particle concentrations greater than 300 $\mu g/m^3$ when using a portable ultrasonic humidifier charged with the purchased distilled water (TDS = 24 mg/L) under single-room conditions. This level is twice the single day PM_{10} standard. Since humidifier use occurs primarily during periods when the occupants are present, long-term exposure to these increased levels may potentially result in either acute or chronic human health hazards. The particulate-induced discomfort to individuals with respiratory problems such as asthma may completely offset the benefits of the higher humidity levels. Comparisons of the TDS levels of the Boise water used in this experiment with other municipally supplied water sources (*6*, *7*) reveal that similar results could be expected across the nation from homeowners who use tap water for humidification. The data suggest that ~90% of the contents dissolved in the water are emitted into the indoor environment in the respirable fine fraction size range. Ultrasonic humidification, and to a lesser degree impeller humidification, could disperse waterborne impurities such as lead, aluminum, asbestos, or dissolved organic gases if they are not removed from the water. Steam humidifiers appear to produce no measurable increase in particulate levels. As noted in the review and promulgation of the PM_{10} standard, long-term exposure to extremely high particle concentrations may result in chronic respiratory problems (*11*). The elevated particle concentrations observed in the single-room experiments raise concerns regarding potential health effects that may result from extended exposures to the high aerosol concentrations. Users should be aware of the potential respiratory irritations and health hazards that may result from the use or improper treatment of tap water in some commercially available portable home humidifiers.

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Medical and Biologic Effects of Environmental Pollutants

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10

Manganese Tricarbonyl Compounds

The industrial hazards associated with the handling of various forms of manganese and manganese ores in mining, steel production, and battery fabrication have been dealt with in preceding chapters. The industrial hazards are circumscribed, and control measures are known. Concerns about public health are related to the aerial discharge of manganese substances that are then inhaled by persons who live in the immediate vicinity and to the occasional infiltration of local water systems with significant amounts of manganese, mostly through location of solid-waste disposal facilities or through contamination of water supplies from sanitary landfills.

Manganese carbonyl compounds hold promise as smoke inhibitors and combustion improvers in fuel oils and as octane improvers in automobile gasolines.

Metal carbonyls are formed when carbon monoxide reacts with so-called transition-series elements at appropriate temperatures and pressures. Carbonyls represent a significant medical hazard: at least one, nickel carbonyl, is carcinogenic, and iron carbonyls, like nickel carbonyl, produce respiratory distress, limb weakness, and tremors.[75] Methylcyclopentadienyl manganese tricarbonyl, $CH_3C_5H_4Mn(CO)_3$ or $C_9H_7O_3Mn$, variously referred to as MMT, CI-2 (for "combustion improver-2"), and AK-33X (for "antiknock 33X"), contains 24.7% (by

weight) of manganese. It is currently used as an additive to fuel oil for inhibiting smoke formation and improving combustion and as an antiknock additive to gasoline, usually as a supplement to the common lead antiknock compound, rather than as a replacement. If the gasolines to be marketed in the future for use as automobile fuels are required by law to contain no lead or significantly less lead than they now contain, the consumption of MMT might have considerable possibility for growth. MMT is toxic in itself, and its use as a fuel additive results in the discharge of manganese to the air. The ultimate fate of the discharged manganese is not definitely established. Thus, a potential public-health hazard must be considered, in addition to the industrial hazard.

TOXICITY STUDIES

It is useful to distinguish the hazards of industrial exposure from those of environmental exposure. Handlers of manganese tricarbonyl compounds are exposed to them and their fumes directly, whereas the general population is exposed only to their combustion products, which may be significantly different.

Two studies by Arkhipova *et al.*[25,26] investigated the problem of exposure. In the first study, laboratory rodents were given cyclopentadienyl manganese tricarbonyl (not the methyl form) at 20 mg/kg or more in a single intragastric feeding. The animals that survived the test for several days appeared sluggish and indifferent to some types of external stimulation. White mice were more resistant than white rats and did not die at doses below 70 mg/kg. The threshold of neuromuscular electrostimulability dropped from an average of 9.6 mA to 5.5 mA, indicating increased sensitivity. Similarly, white rats that received 5 mg/kg daily for 2 months showed slightly lowered neuromuscular thresholds.

The second study investigated sensitivity to the compound when it was inhaled. Rats, guinea pigs, and rabbits were exposed in chambers that contained 0.0007–0.002 mg/liter (average, 0.001 mg/liter) for 4 h/day for 7 months. The rats exhibited no outward manifestations of poisoning throughout the entire exposure period. The authors noted that the threshold of neuromuscular excitability rose 7 months after the experiment began. The data presented, however, also showed that the threshold fell to the preexperimental point in the eighth month, which made interpretation difficult. The authors concluded that the danger from acute poisoning by inhalation was not very great.

Toxicity studies have also been conducted in American laboratories with the methyl form of the compound. The potential hazards of ac-

cidental oral intake, percutaneous absorption, and inhalation were investigated. Not unexpectedly, the oral LD_{50} for a single dose is variable, differing among and even within species, for it depends on the sex of the animal, the concentration of the material presented, and the nature of the vehicle carrying the compound. For example, there is some belief that the toxicity is higher when peanut oil or kerosene is the vehicle, rather than water, for the compound is relatively insoluble in water. Studies in both the United States and Russia indicate that the compound is not particularly irritating to the skin or to the eyes. Usually, the industrial vehicle that presents the exposure (gasoline, fuel oil, etc.) is as toxic or as irritating as the manganese compound.

Specifically, E. A. Pfitzer, S. O. Witherup, E. E. Larson, and K. L. Stemmer (unpublished data) analyzed the toxicity of MMT in different laboratory species for all three accidental routes of contact and the intravenous route. The toxicity depends on the species (rats are more susceptible than mice, guinea pigs, rabbits, or dogs). Females are more sensitive than males. The data are not entirely consistent, owing in part to the small number of animals used for each experimental combination. The approximate acutely toxic oral dosages of MMT in the different animals are as follows: rats, 9–176 mg/kg; mice, 350 mg/kg; guinea pigs, 900 mg/kg; rabbits, 95 mg/kg; and dogs, 600+ mg/kg. The acute skin LD_{50} of undiluted MMT is about 1,700 mg/kg (24 h of exposure for male rabbits). A 10% solution in peanut oil in contact with the abdominal skin of rats for 6 h is toxic at 665 mg/kg. Finally, inhalation toxicity is a function of both concentration and duration of exposure. A crude approximation to acute lethality is 500 mg/m^3-h; i.e., if the product of the vapor concentration (in milligrams per cubic meter) and the exposure (in hours) exceeds 500, roughly 50% of the exposed laboratory subjects (except for guinea pigs) will die.

Pfitzer *et al.* also conducted a series of studies of repeated inhalation exposures. Mice, rats, guinea pigs, rabbits, cats, and dogs were exposed for 7 h/day, 5 days/week, up to 30 weeks. Concentrations of 14–17 mg/m^3 produced mortality in rats and mice but not in the other species. Lower concentrations for comparable exposure periods produced no mortality in any species.

They also found that addition of the compound to gasoline at concentrations up to 16 mg/ml and repeated application to the skin produced no adverse effects that were not attributable to the gasoline itself.

Signs of toxic response appeared promptly after exposure by all routes and included mild excitement and hyperactivity, tremors, severe tonic spasms, weakness, slow and labored respiration, occasional mild clonic convulsions, and terminal coma. The animals that survived the convulsive episodes failed to thrive, lost weight rapidly, and died after a few days. With sublethal exposures, after undergoing temporary weight loss, some appeared to recover without sequelae in 2–6 weeks. As expected, the primary pathologic effects occurred in the kidneys and livers of animals that died or were sacrificed after oral, cutaneous, or intravenous exposure. Inhalation at lethal concentrations produced pulmonary changes as well.

As a result of these investigations, a threshold limit value of 0.2 mg/m^3, or 0.1 ppm (expressed as manganese), was proposed in 1970 for industrial exposure.

PUBLIC-HEALTH HAZARD

Smoke Inhibition

In a study of fuel additives used for controlling air pollution from distillate-oil-burning systems, the Office of Air Programs, Environmental Protection Agency, determined the emission of manganese associated with the addition of MMT to a No. 2 oil at a concentration of 1:9,000 to be 1,219 $\mu g/m^3$, or 20 mg/kg of fuel.[328] Speaking generally for seven fuel additives tested, the report states that "an analysis of the particulate forms emitted revealed in nearly all cases metals in additives are emitted as metal oxides." Elsewhere, the same report states that several of the metal-containing additives, including MMT, reduced particulate emissions but questions the advisability of their use because the toxicity of the emissions is unknown. A producer of MMT claims that "normal combustion processes convert it readily and completely to innocuous oxides" and reports that "during combustion of these fuels the MMT is converted to solid manganese oxide (our studies usually showing Mn_3O as product)" [Ethyl Corporation communication to the National Research Council (NRC)]. Manganese trioxide has also been found (Ethyl Corporation communication to the NRC).

Other studies of the use of an unnamed manganese additive in distillate oils fueling gas turbines disclosed small deposits of manganese trioxide and manganese sulfate monohydrate in the hot-gas path on disassembly of the turbine after running 36 h with a fuel manganese content of 100 ppm. "Stack analyses were attempted, but oxides of manganese could not be detected. This is not surprising since the concentration calculated to be about 1 ppm. Analyses for oxides of sulfur and nitrogen were made also, and it appears that there may be a beneficial effect on oxides of nitrogen by use of the additive."[483] The aforemen-

tioned EPA study, however, reported that none of the additives reduced nitrogen oxide emissions in the test program.[328]

Ethyl Corporation is apparently the sole producer of MMT, except for experimental quantities made in the USSR. There are other organic manganese compounds on the market as combustion improvers, but the quantities used reportedly amount at most to only one tenth that of MMT. Production of MMT for the last 5 years has been at the rate of 450,000 kg/year, made at a multiproduct facility at Orangeburg, S.C. It is claimed that, as an additive for fuel oils fed to turbines, it provides an environmental benefit in nearly eliminating visible smoke. When it is used as an additive to oils used as boiler fuel, the smoke is less dense, sulfur trioxide and its associated "acid rain" are reduced, and deposits on the boiler tubes are reduced, are more easily removed, and are less corrosive (Ethyl Corporation communication to the NRC). A maximal manganese emission of 0.3 kg/h has been estimated for a power plant using MMT (Ethyl Corporation communication to the NRC).

Gasoline Additives

If manganese compounds do indeed become commonplace for their antiknock capability, the amount of their combustion products in the atmosphere will increase considerably. Toxicity will depend in part on the precise nature of the combustion products, for more than 99% of the organic manganese is consumed in combustion, and the exhaust discharge is therefore inorganic (Ethyl Corporation communication to the NRC). No long-term studies for carcinogenicity of the exhaust gases are available. What the exhaust products will be is not known exactly, but manganese tetroxide, believed to be one of the more toxic manganese oxides, will be one of them—doubtless the predominant one. The form of the manganese and the possibility of chemical reaction that results in the formation of hazardous products in the atmosphere are disputed. The absence of definitive quantitative data on their toxicity points to the necessity for further research, inasmuch as such data will be needed before the use of these substances becomes widespread.

If MMT were used as an antiknock supplement in 50% of the gasoline used in the United States in the proportion of ¼ g of manganese per gallon of gasoline, the producer estimates that "the most this would add to urban air would be 0.05 to 0.2 micrograms of Mn/m^3" (Ethyl Corporation communication to the NRC). This is based on two studies [319,485] of lead in urban air and the assumption that manganese and lead emissions to the atmosphere are proportionate, with the manganese being one twentieth the lead. If MMT were to be used as a primary antiknock—

that is, in the range of 1.0–2.0 g of manganese per gallon—then, by extrapolation, emission of manganese to the atmosphere would be increased to ranges of 0.2–0.8 to 0.4–1.6 μg/m^3. However, problems of spark-plug life and exhaust-valve life that accompany use at high manganese concentrations suggest that it is unlikely that a concentration of more than ½ g/gal will be used.

CONCLUSIONS

As is the case for other forms of manganese exposure, more is known about industrial hazards of MMT than about its public hazards. The exhaust products of MMT combustion are specific forms of manganese. Experience with it is extremely limited. No information is available on very long exposures at low concentrations or on exposures of special groups, such as the aged, the chronically ill, the pregnant, or those under chronic medication. The general subject of the relation of the organometallic manganese fuel additives to the problems of air pollution appears to require considerable further study.

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Environmental risk factors in Parkinson's disease

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Article abstract—To investigate possible risk factors for Parkinson's disease (PD) we conducted a case-control study of 150 PD patients and 150 age- and sex-matched controls. We interviewed and examined all 300 subjects. We collected demographic data including lifetime histories of places of residence, source of drinking water, and occupations such as farming. Subjects completed a detailed questionnaire regarding herbicide/pesticide exposure. Rural living and drinking well water were significantly increased in the PD patients. This was observed regardless of age at disease onset. Drinking well water was dependent on rural living. There were no significant differences between cases and controls for farming or any measure of exposure to herbicides or pesticides. These data provide further evidence that an environmental toxin could be involved in the etiology of PD.

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The cause of Parkinson's disease (PD) is unknown. Parkinsonism occurred as a sequela of the epidemic of encephalitis in 1917-1926,[1] but there is no evidence that PD is related to an infectious process.[2] Studies of monozygotic twins have found a low concordance rate suggesting a limited role for heredity.[3-5] Age-related loss of the nigrostriatal dopamine system occurs but is insufficient to cause parkinsonism.[6,7] It would therefore appear that PD is acquired. The discovery that the clinical, biochemical, and pathologic features of PD[8,9] are caused by the chemical 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP) suggests that a similar neurotoxin may cause PD. A plant-derived excitatory neurotoxin may be responsible for the Guamanian amyotrophic lateral sclerosis-parkinsonism-dementia complex (ALS-PDC).[10] Several investigators hypothesized that exposure to an environmental toxin may be responsible for PD.[11-13] Epidemiologic studies have indicated that living in a rural environment, farming, drinking well water, and occupational herbicide/pesticide exposure may be risk factors for PD.[14,15] The state of Kansas is a suitable location to study these variables because of its combination of urban and rural agricultural economy. We have therefore investigated these factors in a case-control study.

Methods. One hundred fifty patients with PD and an equal number of age- (±2 years) and sex-matched controls were studied. PD patients were randomly selected from the Movement Disorder Clinic (University of Kansas Medical Center) and control subjects were attending neurologic and medical clinics (University of Kansas Medical Center). These clinics are university based and receive referrals from the entire state of Kansas. The diagnosis of PD was based on the presence of 2 or more of the cardinal signs of the disease (tremor, rigidity, bradykinesia, and postural instability) and responsiveness to levodopa therapy. All patients were examined by the same neurologist (W.C.K.). Age at disease onset was defined as the age at which the 1st symptom became evident. Patients with atypical features suggesting a multiple system atrophy or postencephalitic or other forms of secondary parkinsonism were excluded. All control subjects were examined, and those with any parkinsonian signs were excluded. Individuals with exposure to neuroleptics and severe dementia were not included in the study. Information was collected by means of a questionnaire administered by a trained interviewer in a face-to-face interview with the subject and family, if available. Sociodemographic data were obtained including the number of years spent in rural versus urban living, number of years spent farming, number of years drinking well water, and exposure to herbicides or pesticides. Rural living was defined as residing in a town with a population less than 2,500 people (U.S. Bureau of Census criterion). The population of cities in

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Table 1. Matched pairs, odds ratios, and chi-square values for potential risk factors and Parkinson's disease

Risk factor	Matched pairs* ++	+−	−+	−−	Odds ratio	χ^2	*p* value
Living in rural residence	58	47	25	20	1.9	6.72	0.01
Well water drinking	59	45	27	19	1.7	4.50	0.03
Farming	44	48	36	22	1.3	1.71	0.19
Herbicide/pesticide use	39	39	37	35	1.1	0.05	0.82

* Matched pairs are described so that the 1st symbol represents the case and the 2nd symbol represents the control. A positive exposure is identified by a "+," a negative exposure by a "−".

which people lived was verified by checking data available in the U.S. Census Bureau for each city at the time the subject lived there. Quantification of herbicide/pesticide exposure included the type of exposure (eg, aerial, direct application, sprayer), the number of years exposed, the number of acres to which herbicides were applied, the type of crop on which chemicals were used (corn, wheat, sorghum, or pastureland), and the type of herbicides/pesticides employed. Subjects were asked to check their records in order to identify specific chemicals they used. These questionnaire items were previously used in a study of the relationship of herbicides and pesticides with lymphoma in Kansas.[16] The number of acre-years (acreage multiplied by the number of years of use of herbicides) was calculated for both cases and controls. Twenty patients were re-interviewed as a check for reliability 4 to 13 months after initial interview. Statistical analysis was performed using McNemar's odds ratio and chi-square tests, analysis of variance, and multiple logistic regression, with alpha set at 0.05. The method of Norman et al[17] was used to test interdependency between variables.

Results. One hundred fifty cases (89 men and 61 women) had PD for an average of 7.3 years. The mean age of PD patients was 66.0 years compared with 66.3 years for controls (range, 39 to 84 years for both groups). Common diagnoses in control subjects were headaches, back pain, heart disease, diabetes, and hypertension. Current residential profiles indicate that 60% of PD patients and 66% of controls were now residing in the Kansas City metropolitan area. There was a statistically significant difference in the number of years that PD patients spent living in a rural environment as compared with controls (table 1). One hundred five PD patients, mean age 66.1 years, had rural exposure compared with 83 controls, mean age 66.5 years. The greatest difference was seen in the 1st decade of life and the difference became progressively smaller until there was no difference by the 5th decade. This relationship was independent of age at onset of the disease. The mean number of residences was 5.4 for cases and 5.6 for controls. The mean number of years drinking well water was significantly greater in the parkinsonians than in the controls (table 1). One hundred four PD patients, mean age 65.8 years, had drunk well water compared with 86 controls, mean age 67.3 years. This relationship was also greatest in the 1st 40 years of life and was independent of age at disease onset. A comparison of the interdependency of rural residence and well water drinking (table 2) shows the well water was dependent on rural living. Odds ratios were for well, rural controlled, 1.06 and for rural, well controlled, 1.35. The difference between cases and controls regarding the number of individuals who reported they had ever farmed as an occupation was not significant (table 1), nor was there a significant difference in the number of years of farming for the 2 groups. There was almost no difference between cases and controls reporting exposure to herbicides or pesticides at some time in their life (table 1). When we examined the differences between cases and controls with respect to number of years of exposure, type of herbicide, circumstances of exposure, number of acres or types of crops on which herbicides or pesticides were employed, a relatively weak association of exposure to 1 crop's herbicides/pesticides (corn) with parkinsonism was found. Numbers here were small, however, and *p* values were of marginal significance. In the face of the large number of tests of significance which had been performed, we discounted these results until further investigation is done. Retesting showed an average reliability of 91% for the factors studied (range, 80 to 100%). Because of the likely interconnection between the variable of rural residence and other measures, we submitted our data to multiple logistic regression which showed that only the number of years of rural residence was significant, $p = 0.033$.

Table 2. Relationship of rural residence and drinking well water for case/control comparison of 2 risk factors*

Well water	Rural residence: Case > Control (+ −)	Case = Control (++, −−)	Case < Control (− +)	Total
Case > control (+ −)	28	17	0	45
Case = control (++, −−)	19	45	14	78
Case < control (− +)	0	16	11	27
Total	47	78	25	150

* Number of pairs shown.

Discussion. Our findings suggest that some factors associated with living in a rural environment increase the risk for developing PD. Three previous studies in North America and 1 study in Hong Kong, although all using different methods, have reported similar results. Rajput et al[18] found that all of the 15 life-long

Saskatchewan residents in his clinic with onset of PD at less than age 40 had lived exclusively in communities with populations of less than 140. The probability of this occurring by chance was less than 1.47×10^{23}. In 100 consecutive PD outpatients, Tanner et al[19] found those with onset at age less than 48 years to be more likely to have lived in a rural environment (town with a population less than 1,000). In a mail survey of 1,100 PD patients, those with disease onset before age 48 were again more likely to have lived in a rural environment than those with onset after age 54. Barbeau et al[20,21] estimated PD prevalence in Quebec from public health records of L-dopa sales, and found a higher estimated prevalence in rural areas. Ho et al,[15] in a case-control study in Hong Kong, found that rural living increased the risk 5-fold compared with those who had never lived in rural areas. Despite the methodologic differences in these studies, the persistent association of rural living and PD suggests that some aspect of rural living increases the risk for PD.

The observation that the toxin MPTP can cause a syndrome strikingly similar to PD suggests that a similar compound, if environmentally present, might be etiologically related to PD. MPTP is a pyridine similar in structure to a number of agricultural chemicals which may be environmentally present, such as paraquat.[22] Alternatively, compounds with similar mechanisms of action might be environmentally present and play an etiologic role. Aquilonius and Hartvig[23] employed pharmaceutical records of L-dopa use to identify a regional distribution of parkinsonism in Sweden. Saw and paper mills and steel alloy industries (located in nonagricultural, nonrural areas) were prevalent in the county where the most PD cases occurred. They postulated that heavy metals were possible toxins causing parkinsonism. A strong north-south gradient (greater in the North) for the disease in the United States has been shown using death rate data,[13] and a lower prevalence of parkinsonism has been reported in newly or nonindustrialized countries.[14] PD may be occurring at a younger age at onset, perhaps because environmental risk factors are becoming more common.[24] Furthermore, it has been reported from postmortem material that nonparkinsonian rural residents had lower substantia nigra cell counts than urban residents of a similar age.[25] These observations suggest that environmental factors may predispose to the development of parkinsonism. Our data confirm the risk of the rural environment and suggest that exposure before age 40 is important.

Our study also found that drinking well water in childhood and early adulthood increased the risk of PD when it was evaluated as a single variable. Multiple variable analyses indicated its dependency on rural living. Four other studies have also found drinking well water to be associated with an increased risk for PD.[14,16,18,19,26] Several of these studies were performed in young onset PD, since exposure to a putative toxin may have been greater in this group. These patients were more likely to have drunk well water and lived in a rural environment. Although well water drinking is common in rural communities, and may be merely an epiphenomenon, it is possible that ingestion of a neurotoxin through drinking water may relate to the development of PD. Many agricultural chemicals are leached from soil into ground water, where concentrations may build since there is relatively little turnover of ground water.[27,28]

We did not find a definitive association between exposure either to specific farm chemicals or to herbicides/pesticides in general and PD. Three previous case-control studies, performed in Madrid, Spain, Quebec, Canada, and Hong Kong, did find such an association.[15,19,26] In China, a case-control study found an increased risk for PD associated with exposure to industrial chemicals including, but not limited to, pesticides and herbicides.[29] Since it is likely that only certain chemicals are responsible for PD, these contradictory results may reflect variations in farming practices in different areas, with consequent exposure to different chemicals or chemical combinations. Toxicity is determined by a large number of factors, such as dose and duration of exposure, body temperature, level of exertion, and metabolic or nutritional state.[30] Variations in any of these factors might explain differences in results in different studies. In the present study, only direct exposure was investigated, and it is possible that individuals were exposed to these chemicals through drinking well water, ingesting exposed foods, aerial spraying, or by some other mechanism. Pesticides were used minimally in the 1st half of this century and a changing incidence of PD over time has not been documented.

It is possible that certain occupations such as farming may increase the risk of developing PD. However, the relationship of occupations to PD has not been adequately studied. In our investigation we found that working on a farm did not increase the risk for parkinsonism. However, farming practices vary from area to area and it is possible that farming in certain locations may be associated with PD. In a geographically defined survey of 3,097 rural Iowans who were at least 65 years old, the association of 25 or more years of farming and various disease states was examined.[31] Health status was determined by subject self-reporting. Some patients were too ill to participate. Farm men were reported to have a lower prevalence of PD than non-farm men. However, case ascertainment in this study was seriously compromised by lack of medical examination, age and work year restrictions, lack of accounting for subjects who moved out of the area, and bias introduced by the "healthy worker" effect. However, farming was found to increase the risk of PD in the study in Hong Kong.[15]

The search for a putative neurotoxin in the environment as an etiologic agent for PD will be difficult. It is thought that there may be a long preclinical phase associated with PD.[22] Chronic, low-dose exposure may account for a slow progression of the disease process. A long latency between exposure to a neurotoxin and the expression of clinical signs may occur in ALS-PDC.[10] It has also been proposed that a brief exposure during a crucial time in life might trigger the disease process.[22] The identification of candidate chemicals is a formidable task.

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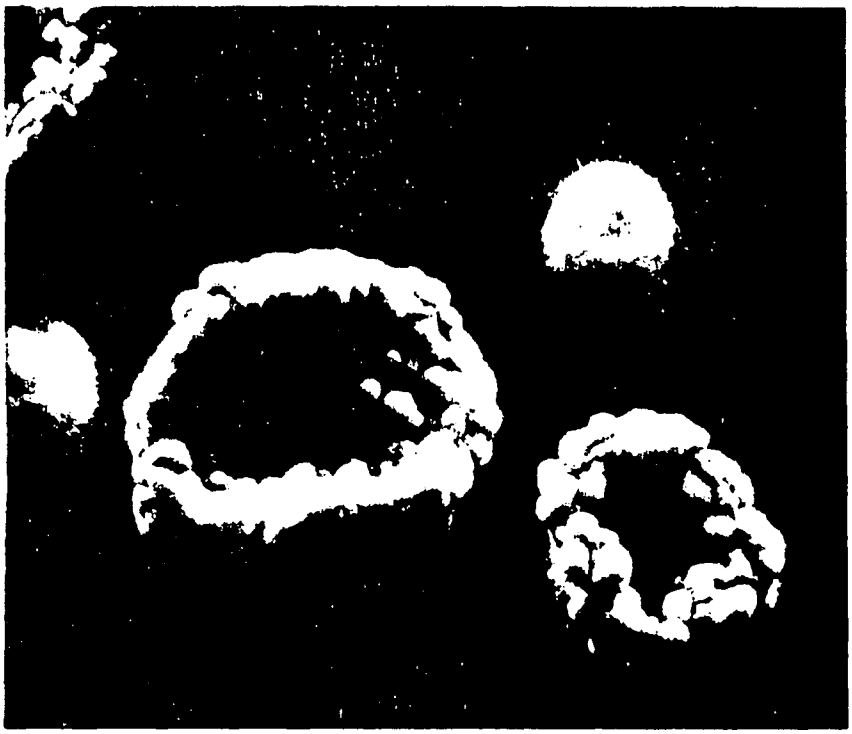

***Nocardia*, a common soil bacteria, can produce the neurological symptoms of Parkinson's. It may even turn out to be a cause for the disease.**

PARKINSON'S BUG

They can't stop trembling and often can't start walking. This is the lot of victims of Parkinson's disease, which cripples the central nervous system. Despite years of research, the cause of Parkinson's has remained a mystery. Now Blaine Beaman, a microbiologist at the University of California at Davis, says that at least part of the answer might be right beneath our feet.

Nocardia, a common soil-dwelling bacterium, can enter your body when you inhale dust. Although most strains are harmless, some can cause brain infections. Recently, after injecting one of these strains into a group of white mice, Beaman noticed that some of the rodents developed head shakes and other neurological symptoms resembling those of Parkinson's.

When he examined the brains of these mice, Beaman learned the resemblance went even deeper. "The bacteria had infected the same brain area affected in Parkinson's patients," he says. This region produces the neurotransmitter dopamine, which is essential to the brain's control of body movements; Parkinson's patients all have drastically reduced levels of dopamine.

Since doctors try to alleviate Parkinson's symptoms by injecting patients with L-dopa, a substance the body can turn into dopamine, Beaman decided to try the drug on the mice.

"We injected the head-shaking mice," says Beaman, "and lo and behold, every mouse had marked improvement." The shaking stopped or diminished, then returned in a few hours when the drug wore off.

Beaman suspects that an infection with this strain of *Nocardia* not only mimics Parkinson's, it may actually be Parkinson's. Receptors on the surface of brain cells in the affected regions may act as targeting sites for the bacteria. The growing bacteria colonies then invade and kill these cells. Because nearby, noninfected cells are damaged as well, Beaman speculates that the bacteria also produce a toxin.

Beaman has found 25 other *Nocardia* strains that produce Parkinson's symptoms. But even if the bacteria don't turn out to be behind the disease, the symptoms they produce make them invaluable. "At this point," he says, "the *Nocardia*-mouse model is the best one we've got for studying Parkinson's."

CLEANER LIVING THROUGH MAGNETISM

On the surface Lake Windermere still looks like one of the jewels of England's gorgeous Lake District. Down below, however, things are getting messy. Discharge from nearby towns is pouring into the lake, depleting its oxygen supply and killing fish.

But a solution to Lake Windermere's problem may be at hand. The Dutch engineering company Smit Nymegan thinks it has an attractive cleansing device in the form of Aquamag, a giant magnet designed to pull offending substances right out of the water.

The most damaging poisons are phosphates, phosphorous-oxygen ions found in home and industrial wastewater. Treatment plants solve problems with other contaminants by holding the wastewater in settling tanks and allowing some of the material to precipitate out; waste-gobbling bacteria then consume much of what is left. Phosphates, however, are not among the bacteria's favored fare, and they are largely ignored.

According to the company's plan, contaminated wastewater will first be bacterially decontaminated, as before. Before leaving the treatment plant, however, it will go through another cleaning step in which it is mixed with iron chloride or lime, which will bind with the dissolved phosphates and cause them to clump together. Next a gluey polymer and a powder made of the iron-ore mineral magnetite will be introduced into the mix. The polymer will bind the magnetite with the phosphates. Then the entire mix will be pumped through a chamber containing a powerful, doughnut-shaped magnet that will extract the magnetite—and the attached phosphates along with it.

This past spring England's Northwest Water company had Smit Nymegan set up an experimental Aquamag system at the treatment plant serving Lake Windermere. A one-ton magnet achieved a 95 percent phosphate reduction.

Northwest is now awaiting the results of other Aquamag tests before deciding whether to install a permanent, six-ton magnet that the company hopes phosphates will find irresistible. ❑

PHOTOGRAPH BY BLAKE L. BEAMAN